Measurement of Interference in ρ^0 Photoproduction in Relativistic Heavy Ion Collisions

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ρ^0 mesons are copiously produced in ultra-peripheral heavy ion collisions. One ion can emit a photon, which fluctuates to a quark-antiquark pair which scatters off the second ion, emerging as a ρ^0, or the second ion can emit a photon which fluctuates and scatters from the first. These two possibilities are indistinguishable, and so they interfere. The two possibilities are related by a parity transformation, and ρ^0 are negative parity, so the interference is destructive and the cross section is[1]

$$\sigma = |A_1 - A_2 \exp(i\vec{b}\cdot\vec{p})|^2 \tag{1}$$

where A_1 and A_2 are the amplitudes for the two photon directions, $\vec{b}$ is the impact parameter, and $\vec{p}$ the ρ^0 momentum. At mid-rapidity, $A_1 = A_2$ and

$$\sigma \approx 1 - cos(\vec{b}\cdot\vec{p}). \tag{2}$$

Of course, $\vec{b}$ is unknown, and must be integrated over. With this integration, most of the interference cancels out, except for $p_T \ll \hbar/\langle b\rangle$, where the spectrum is suppressed; $\langle b\rangle$ is the median impact parameter.

We quantify the interference by selecting a clean ρ sample, using events with exactly 2 charged tracks, with a $\pi\pi$ invariant mass between 550 and 920 MeV/c^2. We consider two samples: exclusive ρ^0, selected by the STAR topology trigger (2 back-to-back tracks), and ρ accompanied by nuclear excitation; the latter events have a smaller average impact parameter, and so the interference is visible at larger p_T. For both samples, we consider two rapidity ranges, $0.1 < |y| < 0.5$ and $0.5 < |y| < 1.0$. Fig. 1 shows the range $0.1 < |y| < 0.5$ for the ρ^0 accompanied by nuclear excitation [2].

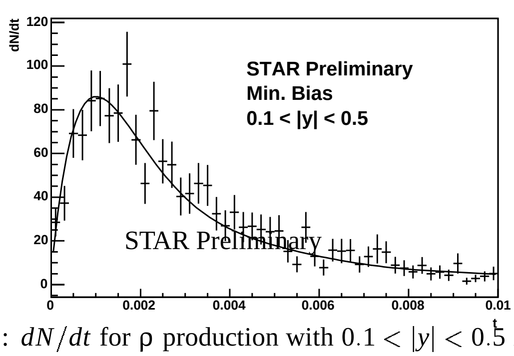

FIG. 1: dN/dt for ρ production with $0.1 < |y| < 0.5$ in 200 GeV per nucleon gold-gold collisions at STAR. The points are the data, while the line is the fit described in the text.

The p_T spectrum is most conveniently studied using $t = p_T^2 + p_{||}^2 \approx p_T^2$. In the absence of interference, dN/dt is well-fit by an exponential function, with the slope depending on the size of the nuclear target. The interference is fit by

$$\frac{dN}{dt} = a\exp(-bt)[1 + c(R(t) - 1)] \tag{3}$$

where a gives the absolute normalization, b is related to the size of the nucleus, c gives the degree of interference and $R(t) = Int(t)/Noint(t)$ is a function obtained from two Monte Carlo's, one with interference, and the other without. $c = 0$ corresponds to no interference, and $c = 1$ corresponds to the expected interference. The fits to all 4 samples show consistent interference; we average them and find $c = 0.93 \pm 0.06(stat) \pm 0.08(syst) \pm 0.15(theory)$.

This interference is of interest in quantum mechanics because the ρ^0 decay before the production amplitudes from the two sources can overlap. Any interference must involve the post-decay wave functions. With the interference, this wave form is non-factorizable, and manifests the Einstein-Podolsky-Rosen paradox [3].

REFERENCES

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